Italian Journal of Agronomy
Rivista di Agronomia

An International Journal of Agroecosystem Management

July-September 2008 Vol. 3, No. 3 supplement

10th Congress of the European Society for Agronomy
15-19 September 2008, Bologna, Italy

ESA

Multi-functional Agriculture
Agriculture as a Resource for Energy and Environmental Preservation

edited by
Paola Rossi Pisa

The Official Journal of the
Italian Society of Agronomy

Italian Journal of Agronomy
Rivista di Agronomia

An International Journal of Agroecosystem Management

July-September 2008 Supplement Issue Vol. 3, No. 3 Suppl.

Contents

Does Conservation Agriculture Mitigate the Negative Effects of Climatic Change on Crop Production: a Modelling Analysis for a Case Study in Zimbabwe

M. Corbeels[1,2], C. Thierfelder[1,3], R. J. Delve[1] and C.H. Porter[4]

[1]Tropical Soil Biology and Fertility Inst. of the Int. Centre for Tropical Agriculture, Zimbabwe, m.corbeels@cgiar.org, r.delve@cgiar.org
[2]UMR SYSTEM, Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France
[3]International Maize and Wheat Improvement Centre, Zimbabwe, c.thierfelder@cgiar.org
[4]Agricultural and Biological Engineering Department, University of Florida, USA, cporter@ufl.edu

Introduction

Conservation agriculture (CA) is seen as a new paradigm to conventional agriculture that uses soil tillage. Three practices underpin CA: (1) minimizing soil disturbance by reduced or zero-tillage; (2) retaining residues on the soil surface and (3) using crop rotations. There is a consensus among climate specialists that Southern African regions will become dryer with more irregular rainfall over by the end of the 21st century. In the global context, maize in Southern Africa is seen as one of the most important crops in need of adaptation investment. Can CA mitigate these negative effects of climate change on crop production? It is known that the water conserving effect of CA practices can stabilise crop yields under drought conditions, but the same effect exacerbates poor drainage. We developed a simulation modelling approach to better understand the potential role of CA under changing rainfall patterns. We present in this paper the results for a case study in Zimbabwe.

Material and Methods

The crop growth model DSSAT-CSM (Jones et al., 2003) was adapted to simulate CA practices, and then calibrated and tested using data from a soil tillage experiment at the Henderson Research Station (17°35' S, 30°38'E, 1136 m.a.s.l.) near Harare in Zimbabwe. The region is characterized by a subhumid subtropical climate with an average annual rainfall of about 880 mm. Rain falls during summer from November until early April. Average annual temperature is about 22°C. The site has a slope of about 5 to 7 % and the soil was classified as a dystric Arenosols. For this study, 2 tillage treatments were considered: (1) the conventional farmer's practice of ploughing the soil to a shallow depth (10 to 15 cm) without retention of crop residues (CT); (2) the no-tillage practice with retention of crop residues (about 2 ton DM/ha) using a direct seeder (CA).
DSSAT-CSM uses daily weather, crop and soil parameters as input to predict growth and yield of a range of crops. Model adaptations included the influence of crop residue cover and tillage on soil surface properties and the soil water balance. With the model we assumed that the following four soil properties vary with tillage: 1) bulk density, 2) saturated hydraulic conductivity, 3) the 'Soil Conservation Service' runoff curve number and 4) soil water content at saturation. The soil properties after a tillage event are input and they change back to a settled value, following an exponential curve that is a function of cumulative kinetic energy since the last tillage operation (Andales et al, 2000). A mulch of crop residues affects three soil water-related processes in the model: 1) rainfall interception by the mulch, 2) reduction of soil evaporation rates, and 3) reduction of surface water runoff.
We ran the model to simulate maize production for water-limited conditions under the present climate using 45 years of daily climatic data (baseline scenario, BS) from Harare and under three plausible future rainfall scenarios for the region (Lobell et al., 2008). These were: (1) a 15% decrease in annual rainfall, RS; (2) a 15% increase in the duration of dry spells, DS; and (3) the combination of scenarios 1 and 2, RDS. Each scenario also comprised a temperature increase of 1.1°C. The scenarios were constructed using the stochastic weather generator LARS-WG (Semenov and Barrow, 1997)

Results

Using DSSAT-CSM we predicted water-limited maize grain yield for the Henderson site under the 4 weather scenarios (including the baseline climate) and for the 2 tillage treatments (CT and CA). Planting date was during the last week of October. For the baseline scenario (BS) simulated maize grain yield was on average about 720 kg/ha higher under CA then under CT (Table 1). This was mainly due to increased water availability as a result of decreased runoff under CA compared to CT. Predicted yields varied broadly, from a minimum of 1003 kg/ha to a maximum of 6483 kg/ha depending on seasonal rainfall amount and distribution. As expected average grain yields for both tillage practices were lower for future climate scenarios (Table 1). The simulation results indicate that the impact of a 15% increase in the duration of seasonal dry spells (DS scenario) is at least as large as that of a 15% decrease in annual rainfall (RS scenario). Under the RDS scenario of decreased rainfall with longer dry spells model predictions suggest a decrease in maize grain yields of about 25 to 30%, which is in agreement with the value (30%) projected for Southern Africa in a broad-scale analysis by Lobell et al (2008).

The cumulative distribution functions of simulated maize grain yield for the BS and RDS climate scenarios under CT and CA are presented in Fig. 1. Under the current climate the probability of producing at least 3000 kg/ha grains is 41 and 67 % for respectively CT and CA. Under future climate, due to water stress the probability drops to respectively 15 and 43%. The results indicate that the negative impact of climate change can be mitigated by adopting CA in the 'normal' years, but with a higher risk of lower yields in the 'good' and 'bad' years.

Table 1: Effect of climate change on maize yield (kg/ha) as simulated by DSSAT-CSM under conventional tillage and CA for the Henderson site nearby Harare, Zimbabwe. Variation coefficient in parenthesis

	BS	RS	DS	RDS
CT	3107	2607	2577	2254
	(0.39)	(0.35)	(0.41)	(0.43)°
CA	3830	3166	3328	2832
	(0.35)	(0.34)	(0.37)	(0.40)

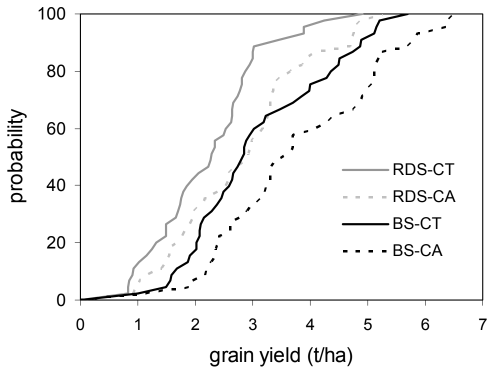

Figure 1. Cumulative probability functions of maize grain yield as simulated by DSSAT-CSM for the BS and RDS climate scenarios under CT and CA practices.

Conclusions

The simulation results show that climate change will have a major impact on maize productivity in the study region. CA practices have a potential to reduce climatic risk for farmers in southern Africa. However, the question remains how these practices fit in their farming systems. Crop residue mulching profoundly alters the flow of resources at the farm, and there are trade-offs in the use of crop residues at farm level. Crop residues, and in particular cereal stover, is a highly-valued fodder for livestock in smallholder farming systems in Africa.

References

Andales AA. et al, 2000. Incorporating tillage effects into a soybean model. Agric. Syst. 66:69-98.

Jones JW. et al 2003. The DSSAT cropping system model. Eurp. J. Agron. 18:235-265.

Lobell DB. et al, 2008. Prioritizing climate change adaptation needs for food security in 2030. Science 319: 607-610.

Semenov MA. and Barrow EM. 1998. Use of a stochastic weather generator in the development of climate change scenarios. Clim Change 35:397-414.